A Systematic Search for Absorption Features In the X-Ray Spectra of Ultraluminous X-ray Sources

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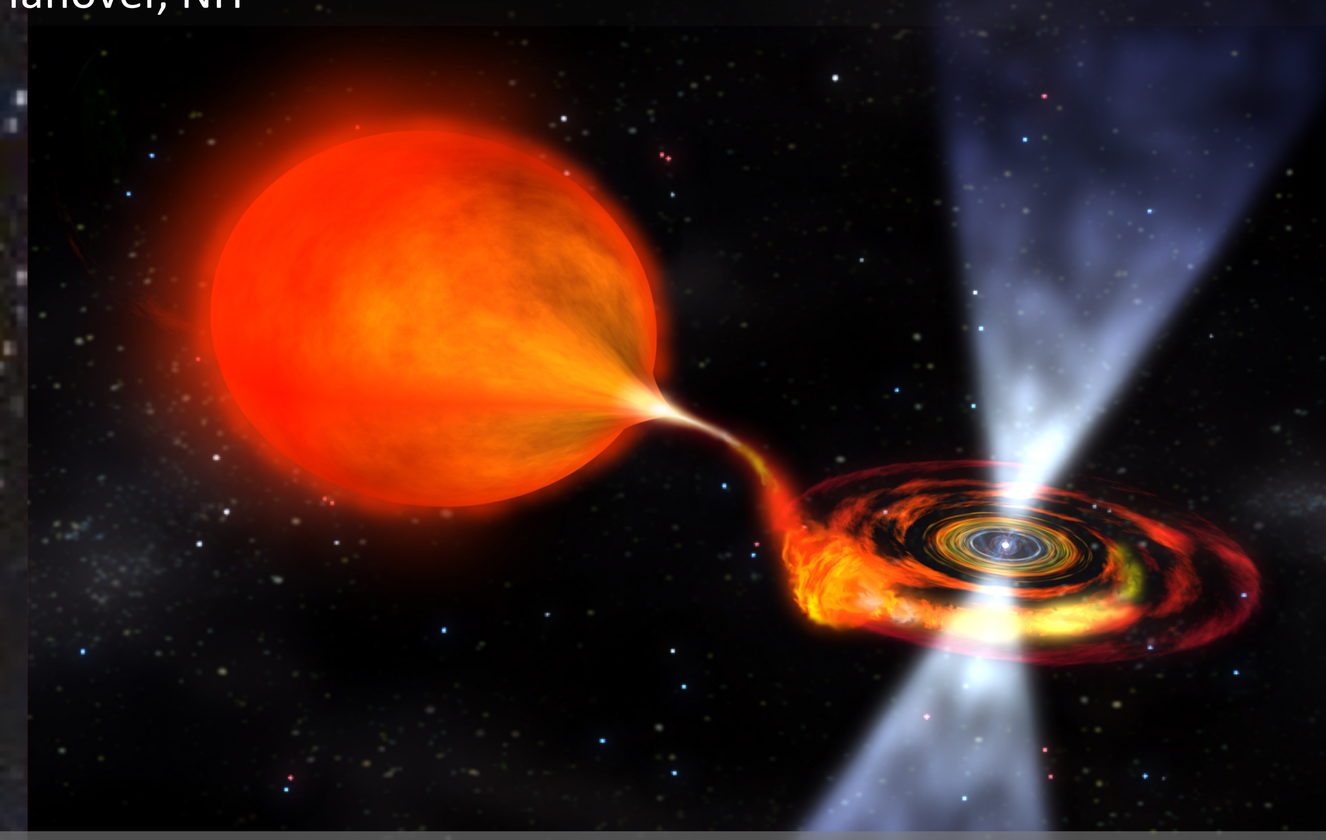
STAR POWER

Ultraluminous X-ray sources (ULXs) are variable, non-nuclear, bright X-ray sources in nearby galaxies independent of the central supermassive black hole. These ULXs have greater luminosities than the Eddington limit of stellar mass black holes or neutron star. These ULXs break Eddington theory because of extreme accretion rates onto a compact stellar remnant, or a black hole.

Some ULXs were recently discovered to be neutron-star powered. Unlike black holes, neutron stars have an intense magnetic field that allow super-Eddington accretion. Using the data from the XMM-Newton and Chandra X-ray observatories, we conducted a systematic search to find cyclotron resonance scattering features (CRSFs) to identify neutron-star powered ULXs. The results provide insight into the analysis techniques for future neutron star-powered ULXs and field strength estimates.



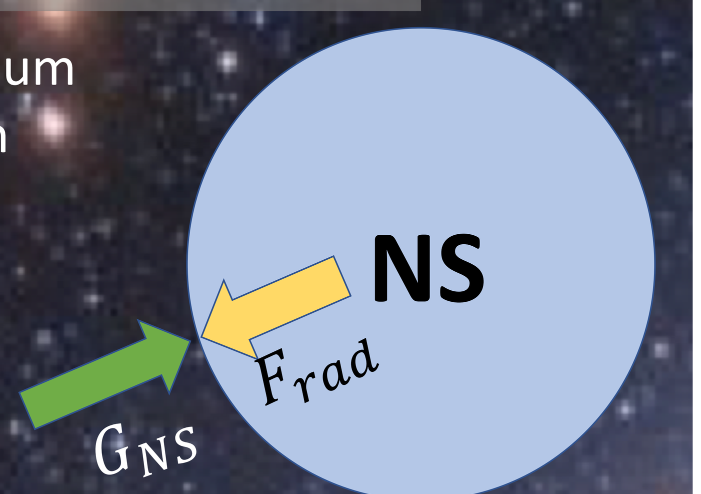
(Left) ULXs are powered by the accretion onto a black hole or neutron star feeding from a stellar companion onto an accretion disk.

EDDINGTON LUMINOSITY

The Eddington Luminosity is the maximum luminosity a star attains when radiation pressure from the star and gravitation pressure are balanced.

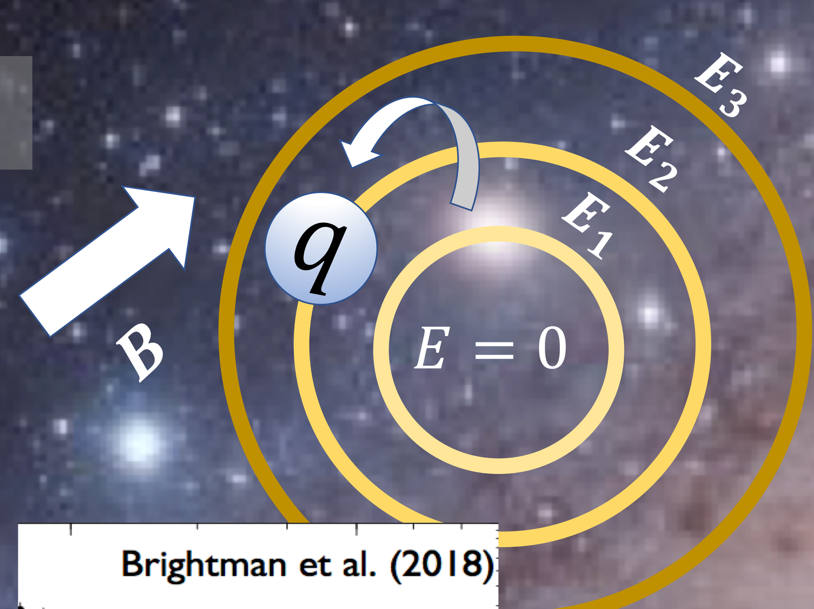
$$\frac{dP}{dr} = \frac{kp}{c} F_{rad} = \frac{GMp}{r^2}, \text{ where } F = \frac{L}{4\pi r^2}$$

$$L_{ed} = \frac{4\pi Gc}{k} M$$

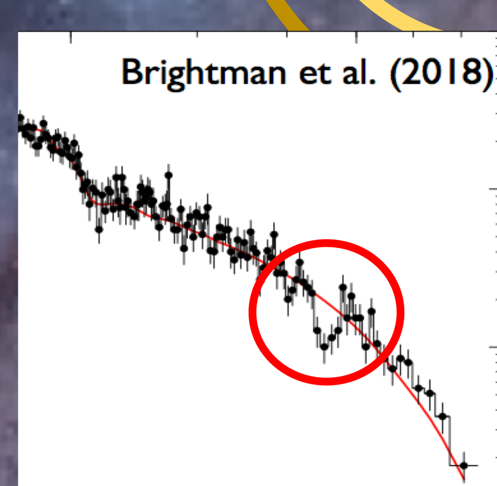


CRSFs

Induced cyclotron lines in spectra imply the presence of a magnetized neutron star and give a measurement of its field strength. A substantial magnetic field on around $10^{14} - 10^{15}$ G would reduce radiation pressure and allow super-Eddington accretion.



(Above) A 2-D representation of Landau levels



(Right) Cyclotron line found in M51's ULX-8 found by M.Brightman, now believed to be neutron-star powered.

METHODS

SYSTEMATIC SEARCH

- Cross-referenced the Serendipitous XMM-Survey to find ULXs with at least 10,000 intensity counts.

SPECTRAL ANALYSIS

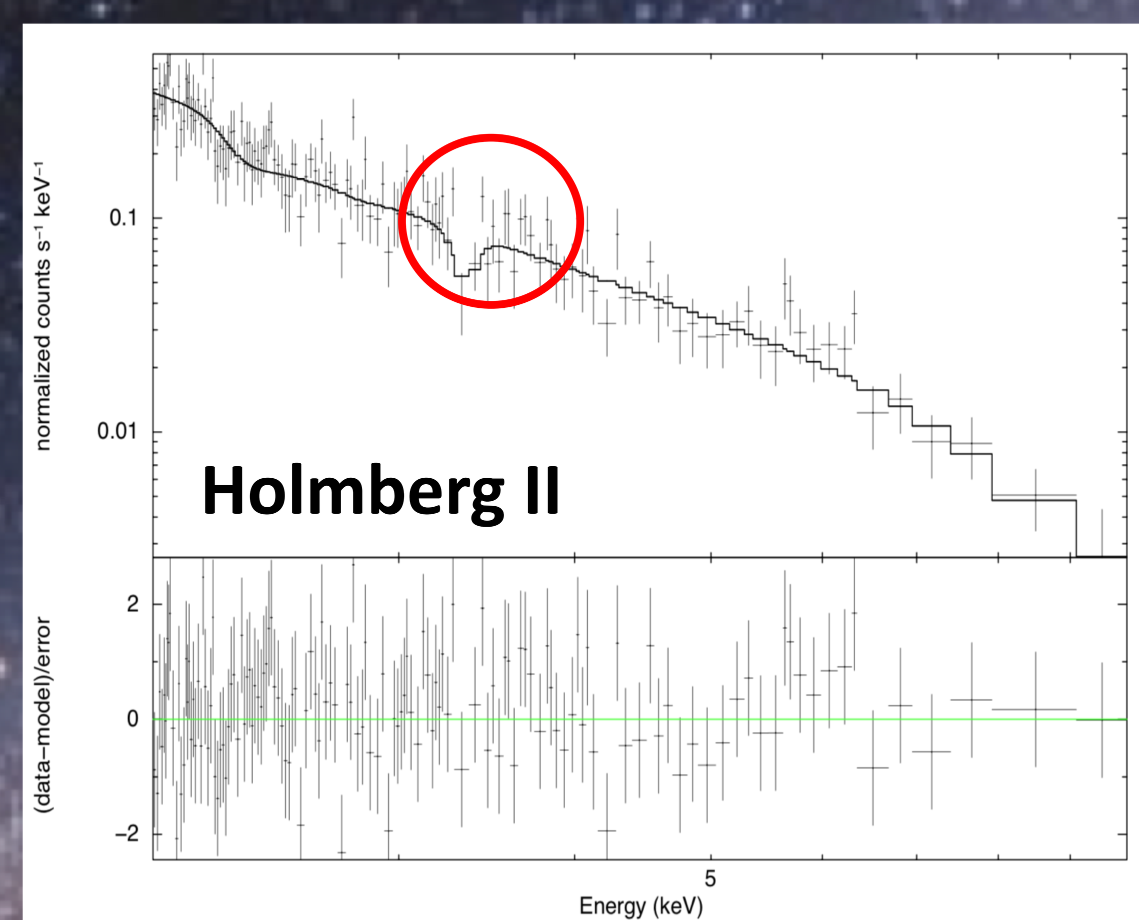
- Reduced XMM/Chandra data and found favorable spectral extraction parameters using Chi Squared test.
- Used spectral fitting software XSPEC to analyze detector data and fitted the spectra with a coupled cutoff power law continuum and Gaussian absorption (zgauss) to find CRSFs
- Ran 10,000 simulations to assess false alarm rates.

RESULTS

We found three strong absorption line candidates for analysis: Holmberg II, IC 342, and M32.

HOLMBERG II

Absorption feature detected in Holmberg II at $E \sim 3.3$ keV at the 2σ level with $\Delta\chi^2 = 6$



IC-342

Absorption feature detected $E \sim 5$ keV at 2σ level with $\Delta\chi^2 = 8$

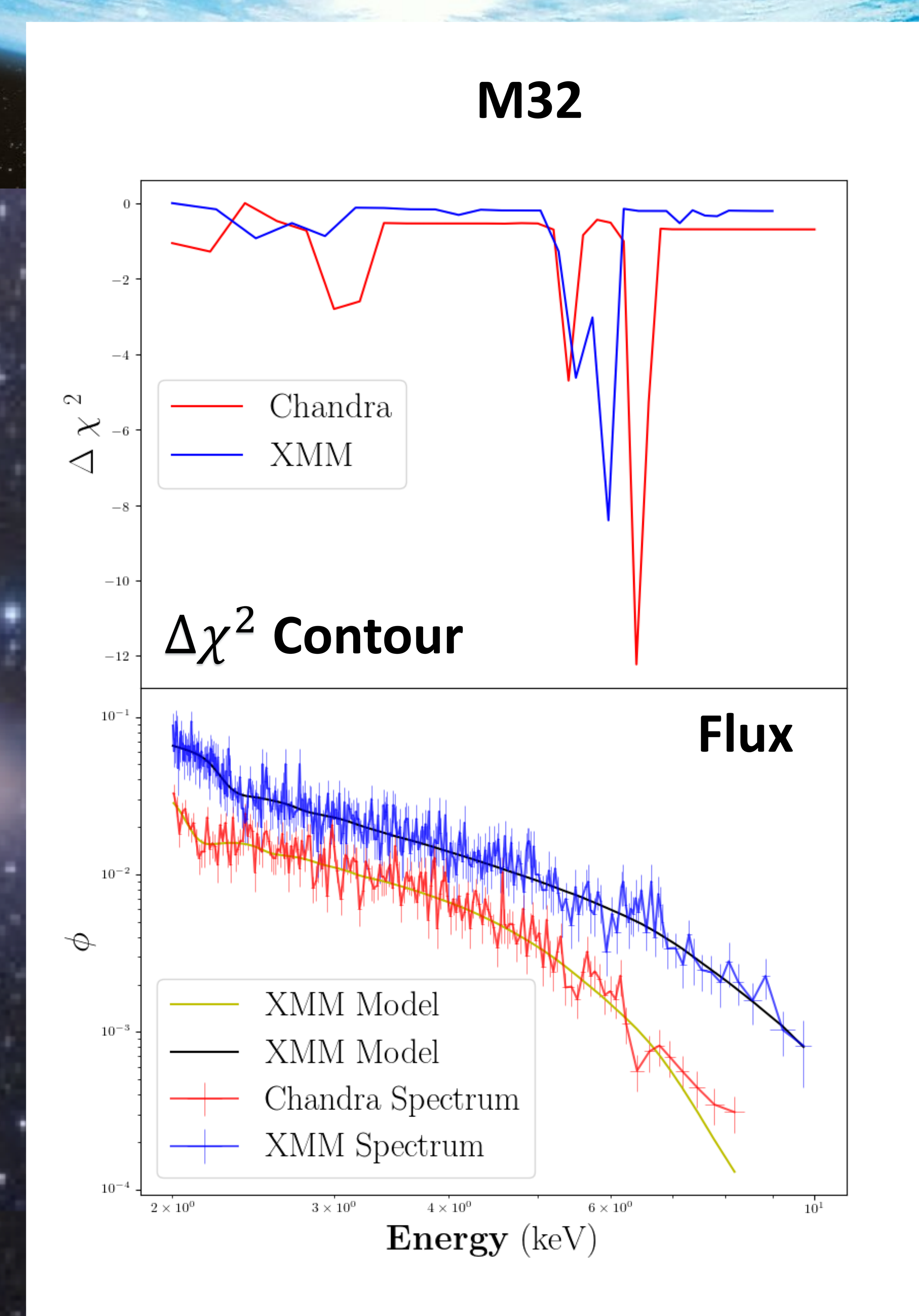
Although IC-342 showed statistical promise, there were no visible features detected within the continuum.

M32

The ULXs observed in M32 are proximate to each other, and therefore needed Chandra data for spatial resolution.

Two absorption lines found:

- $E \sim 6$ keV detected at 3σ level with XMM at $\Delta\chi^2 = 8$
- $E \sim 6.5$ keV detected at 2σ level with Chandra at $\Delta\chi^2 = 12$



CONCLUSION

Different energies between XMM/Chandra M32 observation may be due to

- the magnetic field orientation changing between observations.
- possibility of an Iron outflow at one of the energies.
- a statistical fluctuation in spectral data
- contributions from the two proximate X-Ray sources are additive.

Holmberg II and M32 show the absorption-like features that may be either cyclotron lines or atomic. To consolidate our findings, spectral data needs to be compared across detectors. Future observations are needed to gather more data on these sources.

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REFERENCES

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